PD sensors, similar to those discussed in Paper 10742, were evaluated in a large research project funded by the Canadian Electrical Association (CEA, and now known as CEATI) in the 1980s. Three different designs were evaluated for installation on the grounded enclosure of isolated phase bus (IPB):

- Inspection covers were insulated from the rest of the enclosure
- Foil was installed within the grounded enclosure (and insulated from the enclosure)
- The ground-side metal base of post insulators (used to support the center HV bus) were insulated from ground, and also formed a capacitance to the HV bus.

All three types had a capacitance from between 2 pF to 10 pF. 5:1 RF transformers (by RF Minicircuits) were also sometimes used to lower the cutoff frequency of the coupler. Two such capacitors were installed per phase, to enable the time of arrival (ToA) method to separate stator PD from signals originating between the couplers, and also from signals from the power system (from beyond the second coupler (Figure 1).

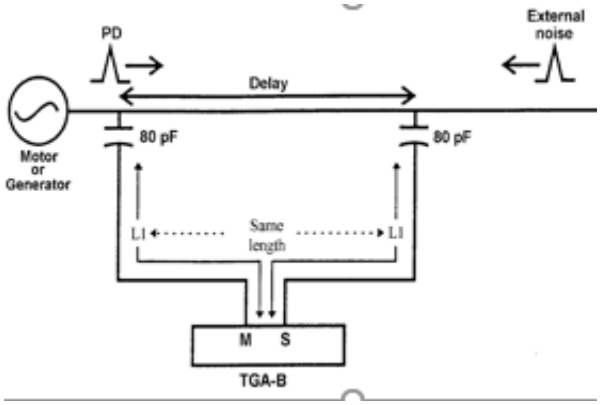

Figure 1: "directional time of arrival" method to separate signals from the three regions

Such couplers were installed on 21 large turbine generators in 2 utilities. After several years of evaluation, this type of coupler was abandoned because:

- The signal magnitudes were much smaller than those obtained from 80 pF capacitors connected to the IPB (Figure 2)
- In practice the capacitance, and thus the measurement frequency could not be controlled within a narrow range, which made comparisons of signal magnitudes between different machines difficult
- In practice, it was not possible to install such non-contact couplers as close as possible to the machine terminals. This increased the risk of noise from cracked or improperly installed post insulators from causing false positive indications.

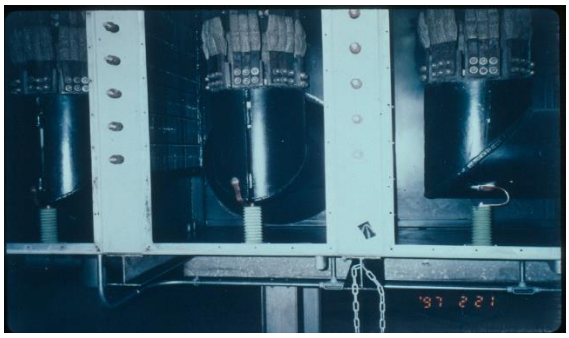

Figure 2: 80 pF couplers connected to the TG terminals. Note that any arcing/sparking from the flexible links will be classed as stator PD by the time of arrival method.

Fixed capacitors (80 pF) galvanically connected to the HV bus overcame these limitations. Such 80 pF couplers have now been installed on >27,000 generators and motors (including 12,000 TGs). The apparent limitation of being connected to the HV bus has been overcome by:

- Use a small capacitance (80 pF) which ensures that the average thickness of the insulation can be made comparatively large – the design electric stress is much lower than that used in the generator stator bars
- The use of mica splittings as the main insulation, which is extremely PD resistant
- Exceeding all the requirements for capacitive coupler reliability in IEC 60034-27-2 and IEEE 1434. This includes subjecting couplers to severe voltage endurance, thermal cycling, and electrical tracking tests, as well as having a PDIV > two times operating voltage.

Since 1994, over 80,000 80 pF couplers have been installed and there have been 0 in-service failures on TGs (there have been a few in-service failures on motors, where the coupler was exposed to heavy contamination and dripping water).

As the authors state, the time of pulse arrival (ToA) method has proven its worth in separating power system noise from stator PD. However, there is a limitation. If any bolt on the flexible links to the generator bushing is arcing, even if it is relatively harmless, this leads to false positive indications. Also a cracked or poorly installed post insulator (again usually harmless) within 1 m of the coupler (assuming a detection bandwidth of 300 MHz) will cause a false indication. If lower detection frequencies are used, the zone where post insulators can cause false indications is longer. Since such issues occur on about 30% of older TGs/IPBs, this led to the development of SSCs (UHF antenna installed within stator slots). SSCs have a significantly lower risk of false indications on hydrogen-cooled TGs equipped with 80 pF IPB couplers [2].

References:

1. H.G. Sedding, G.C. Stone, S. Campbell, “Evaluation of Coupling Devices for In-Service PD Detection on Thermal Alternators”, CEA Report 738 G 631, Nov 1992.
2. G. C. Stone, C. Chan and H. G. Sedding, "Relative ability of UHF antenna and VHF capacitor methods to detect partial discharge in turbine generator stator windings," in IEEE Transactions on Dielectrics and Electrical Insulation, vol. 22, no. 6, pp. 3069-3078, December 2015, doi: 10.1109/TDEI.2015.005180.